TRANSLATION
of
WO 99/64504

Description

Nanoporous interpenetrating organic-inorganic networks

The invention relates to nanoporous interpenetrating organic-inorganic networks, a method of producing them and their use.

Organic polymers are often characterised by good shaping properties and elasticity. However, they are not hard or scratch resistant enough for many applications. Ceramic materials on the other hand are hard and scratch resistant but as a rule they are brittle and not elastic. If it is desired to combine the properties of organic polymers and inorganic ceramics, then it is possible to try to produce an as far as possible uniformly mixed material from both materials. Various formulations in this direction are known.

US-A-4 980 396 describes a composition comprising an organopolysiloxane, a filler of the silica type, an organosilicon compound of the isocyanurate type and an organic solvent. The composition is used in order firmly to bond a fluorosilicon rubber to metal, synthetic plastic and other materials, whereby it is desired to vulcanise a fluorosilicate rubber by atmospheric hot air vulcanisation. The constituent substances are used in the form of a solution or suspension, for example in ethyl acetate as an organic solvent.

US-A-5 342 876 describes a method of producing porous and spherical silicon dioxide particles in which polyacrylamide polymers are used as coagulation growth agents for the coagulation of silica gels. Obtained thereby are silica gel coagulates having a pore volume of 0.3 to 1.0 cc/g. No interpenetrating network of silicon dioxide and polyacrylamide is formed, so that the polyacrylamide can be dissolved out of the body formed. The polyacrylamide thus serves to construct the silicon dioxide body and is not a constituent of an organic-inorganic network.

Furthermore, in various formulations, silicon-organic starting compounds have been used in order to arrive at organic-inorganic hybrid materials. In this respect, it is necessary in the processing of the very expensive silicon organic compounds, to work in an organic

solvent. Both the conduct of the process and also the starting materials are very costly so that the possibilities of using this method are confined to special applications.

This group of methods includes methods of producing nanocomposite materials in which alkenyl silanes are thermally or photochemically polymerised. After polymerisation of the organic constituents, an inorganic network is produced by hydrolysis. During this stage, bulk materials of high density are accessible. These materials are, in turn, extremely expensive.

The object of the present invention is the provision of a method of producing materials with penetrating organic and inorganic networks in very small dimensions and which is based on reasonably priced starting materials and which results in products which have widely adjustable properties. In this respect, it is intended in particular to make aerogels and xerogels of low thermal conductivity and elevated sound absorption, together with composite materials, accessible which combine the properties of organic polymers and inorganic ceramics.

The problem is resolved by a method of producing materials with interpenetrating organic and inorganic networks with a maximum dimensions of 100 nm by

(1) mixing aqueous solutions or dispersions of organic polymers capable of forming polymer networks in aqueous phase, polymer precursors or mixtures thereof and silicon dioxide components;

(2) changing the pH value and/or thermal treatment of the aqueous solution or dispersion to form a gel consisting of interpenetrating organic and silica gel networks, and

(3) drying the gel.

According to the invention, it was found that the above-mentioned materials can be produced according to a method of producing aerogels and xerogels, whereby in addition

to inorganic substances for the production of aerogels and xerogels, organic polymers or polymer precursors are used which, under the conditions in which aerogels and xerogels are formed, are capable of forming organic networks. There now follows a description firstly of the starting materials and then of the various alternative methods.

For forming the organic polymer networks, such organic polymers, polymer precursors or their mixtures are used as are capable of forming networks in aqueous phase.

In principle, all organic, water soluble or dispersible polymers including polymerisates, polycondensates or polyadducts which can be cross-linked in water are suitable for this. Examples are non-ionic polyvinyl alcohol which can be completely or partially saponified from polyvinyl acetate, polyethylene glycol, anionic polymers such as carboxy methyl cellulose and sodium poly(meth)acrylate or other poly(meth)acrylates or cationic polymers, polyamides or polyvinyl amines as well as their mixtures. Also homo- and copolymers of sterols, such as bile acid homopolymers, copolymers or oligomers such as are described in EP-A-0 549 967, or cholesterine may be used. Preferably, in addition to polyvinyl alcohol or poly(meth)acrylates, it is possible to use organic polymers or their precursors which are based on formaldehyde or resins which contain formaldehyde. These are predominantly melamine resins, phenol resins or resorcinol resins. Particularly preferred are melamine-formaldehyde resins which possibly contain solubilisers such as sulphamate and which preferably gel in the pH range from 5 to 6. These polymers ought to be possible of being cross-lined with everyday cross-linking agents such as formaldehyde or glutaric aldehyde in an aqueous medium. Generally, also aliphatic and aromatic dialdehydes, particularly glutaric dialdehyde, aliphatic or aromatic diepoxides or aliphatic and aromatic diisocyanates may be used as cross-linking agents for the organic components.

The organic polymer network is preferably obtained by polycondensation in the aqueous phase. Polymers and polymer precursors which can be radically polymerised in aqueous phase can however also be used.

Melamine formaldehyde condensates are described for example in US-A-5 086 085. Resorcin formaldehyde condensates are described for example in US-A-4 863 218.

Preferably, organic polymers or polymer precursors or their mixtures are selected which, by the adjustment of the pH value or the temperature, polycondense in the same range as the inorganic (silicatic) network.

If polyacrylic acids or bile acid polymers or copolymers according to EP-A-0 549 967 or also other polyacrylic acid or polyacrylic acid amide derivatives are used, then it is possible in addition to exploit their enormous swelling behaviour so that the polyacrylic acids can be used either already cross-linked and in dried form whereby, for swelling, it can be added to a silicic acid sol. The expression "organic polymers, polymer precursors or their mixtures" thus refers to all components which are needed in order to obtain a polymer network in aqueous solution or dispersion. In particular, this expression includes polymers, prepolymers, monomers, cross-linking agents or other substances conducive to polymerisation or cross-linking.

The silicon dioxide components used according to the invention are those components which are capable of forming polymeric networks in aqueous solution. Preferably, water-glass, laminated silicates or silicic acids are used as silicon dioxide components. Metal oxides which are suitable for the sol-gel technique are for example described in C.J.Brinker, G.W.Schere, Sol-Gel Science, 1990, Chapters 2 and 3, Academic Press Inc., New York. Preferred components in this respect are free silicic acid which can be produced for example from water glass by separation of the cations by means of ion exchangers. Such a method is described for example in EP-A-0 658 513. Free silicic acid from which the cations are removed, has a very good compatibility with organic polymers, polymer precursors or their mixtures which are capable of forming polymer networks and can, under the most widely diverse conditions and according to pH value and concentration, form stable sols and gels. Generally, usable silicic acids consisting of sodium or potassium oxide and silicon dioxide are formed. Colloidal silicic acids can also be used.

It is particularly preferred, in a method according to the invention, to use a combination of water glass or, in particular, free silicic acid and melamine resins, particularly commercially available sulphamate modified melamine resins.

As further constituent substances, it is possible to use substances compatible with an aqueous phase and which are conventionally used for forming polymers or silica gels. Fillers preferably used are those in the form of particles, fibres, weaves, fleeces, mats or their mixtures, functional substances such as dyestuffs, indicators, biomolecules, for example as aqueous or non-aqueous solutions, dispersions or suspensions or their mixtures. Examples of biomolecules are proteins such as enzymes, transport proteins, receptors or antibodies. These fillers or functional substances can have a controlled influence on the electrical, dielectrical, optical, mechanical, rheological, sensoric, permative or diffusive properties of the materials contained.

Particularly in the manufacture of heat insulating materials, infra-red opacifiers are incorporated as fillers and serve to reduce the radiation contribution to heat conductivity. Suitable IR opacifiers are for example carbon black, titanium dioxide, iron oxide, zirconium oxide or their mixtures. They can be added to the aqueous solution or dispersion or to the sol.

To improve the mechanical strength of the mouldings or materials obtained, it is likewise possible to add fillers. Particularly, fibres are added, for example in the form of fleeces or mats. As fibre material, it is possible to use both inorganic fibres such as glass fibres or mineral fibres as well as organic fibres such as polyester fibres, polyamide fibres or nylon fibres. The fibres may also be layered, for example polyester fibres may be used which are metallised with a metal such as aluminium. Furthermore, blackened fibres, for example PET fibres blackened with carbon black may be used if it is intended to reduce the contribution of radiation to the heat conductivity of the resulting material.

The fire category of the material obtained after drying is determined by the fire category of the aerogel, of the organic components and of the fibre material. In order to obtain a fire category which is as favourable as possible (flameproof or inflammable with difficulty) of the material, it is preferable to use fibres of a non-combustible material, for example mineral or glass fibres. Examples of fibres which are inflammable with difficulty are melamine resin fibres as well as polyester fibres which it is difficult to set on fire.

Where their use as heat insulating materials is concerned, in order to avoid increasing the heat conductivity by the fibres added, the volumetric proportion of fibres ought to be 0.1 to 30 and preferably 1 to 10% by weight in relation to the dried material. In addition, the heat conductivity of the fibre material should be as low as possible and preferably less than 1 W/mK. By a suitable choice of fibre diameter and/or fibre material, the contribution of radiation to the heat conductivity can be reduced and a greater mechanical strength achieved. To this end, it is preferable for the fibre diameter in the case of non-metallised fibres to be 0.1 to 30 μm and/or in the case of metallised fibres 0.1 to 20 μm.

The mechanical strength of the material obtained after drying is furthermore influenced by the length and distribution of the fibres in the aqueous solution or dispersion. The fibres can for example be incorporated as individual fibres in a disordered or orientated manner. In this case, in order to guarantee an adequate strength of the composite material, they should have a length of at least 1 cm and preferably at least 2 cm.

Similarly, fleeces or mats may be used which are impregnated with a solution or dispersion whereby also a plurality of fleeces or mats may be layered above one another. In the event of the mats being layered in a preferred direction, it is advantageous to change the direction of preference from one layer to the next.

Further constituent substances are

- dyestuffs in typical concentrations in order to establish the colour of the material according to the invention. In principle, any types of dyestuffs may be used either in solution or in dispersion,
- stabilisers, e.g. ultra-violet stabilisers and hygroscopic components, for example polyacrylic acids as well as amines, for example polyvinyl amines or immobilised silyl amines which influence the swelling action and adsorption behaviour of the material,
- flame-inhibiting substances such as are typically used as additives for the polymers employed, e.g. phosphate and bromine compounds as well as IR absorbers,
- indicators, e.g. pH indicators, as well as biomolecules, e.g. proteins such as enzymes, transport proteins, receptors or antibodies such as fluorescent marked antibodies and dyestuffs which alter the optical behaviour (adsorption reflection fluorescence quenching) in the presence of substances which are to be detected.

The constituent substances may be covalent in their bonding or bonded by inclusion in a cavity by virtue of the size or by hydrogen bridge bonds in the composite. It is also possible to use special immobilising techniques such as are known from dyeing technology and biotechnology. It is however important that they are not released during the intended use. The constituent substances may be incorporated prior to, during and/or after the drying process and then preferably prior to any subsequent secondary condensation of the organic network. It is likewise possible additionally to produce a granulate form of the material, to grind it and subsequently to blend it with one or more of the above-mentioned fillers and functional substances.

In the solution or dispersion which is used to produce the materials according to the invention, the ratio by weight of silicon dioxide components to organic polymers and/or polymer precursors preferably amounts to 10 to 98 and particularly preferably 10 to 90 and especially 30 to 80. For the production of aerogels or xerogels, the ratio is preferably 10 to 98, particularly preferably 20 to 90. For the production of composite materials, the ratio is preferably 20 to 90 and particularly 30 to 80.

The aqueous solution used in the method according to the invention preferably contains 3 to 70, particularly preferably 5 to 50 and in particular 5 to 35% by weight constituent substances in relation to the total aqueous solution or dispersion. In this respect, the proportion of polymers and/or polymer precursors amounts preferably to 1 to 50, particularly preferably 1 to 30% by weight, The proportion of silicon dioxide components preferably amounts to 1 to 30 and particularly preferably 1 to 25% by weight.

The aqueous solution or dispersion for forming polymer networks can be produced by any desired suitable methods. For example, separate aqueous solutions or dispersion of the organic and inorganic materials may be produced and then mixed. Also, all materials can be dissolved or dispersed in water one after another. The pH value of the solution obtained in this way is preferably so adjusted that a dwell time needed for the mixing process is maintained until a gel forms from the sol.

Preferably, water is used as the aqueous phase. However, it is also possible to use a mixture of water and organic solvents such as alcohols, polyols, cyclic ethers, etc. In this respect, the proportion of organic solvent, where present, is preferably 0.1 to 10 and particularly preferably 0.1 to 5% by weight. As a rule, working is carried out in water as the aqueous phase.

The aqueous phase with the organic and inorganic starting substances which may be a sol is in a second stage and by changing the pH value and/or by thermal treatment of the aqueous solution or dispersion, transferred to a gel consisting of interpenetrating organic and silica gel networks. By a corresponding adjustment of the pH value, formation of the silicatic network (silica gel) can take place prior to formation of the organic network. However, also silicatic and organic network can be formed in parallel or the organic network may be formed first. By the addition of a base or an acid, and by controlling the pH value, it is possible to control the time for gel formation and for construction of the two networks. The construction of the networks also depends upon whether cross-linking

agents are used for the organic network. Preferably, for gel formation, the pH value is adjusted to 3 to 7.

A solid gel can also be brought about by elevating the temperature to below the boiling point of water or even above it if the pressure apparatus is able to prevent boiling of the water. In this respect, and as a function of the temperature, it is possible to obtain a solid gel over a period from a few seconds to a few hours. Preferably, working is at a temperature of 10 to 90°C and particularly preferably 30 to 85°C in which the time for forming the gel is preferably 0.1 seconds to 2 hours.

The gel obtained in this way can be hardened and aged at elevated pressure in the range from 1 to 30, preferably 1 to 12 bars at a temperature of 10 to 200°C, preferably 5 to 150°C, and in particular 50 to 150°C. In this respect, the pressure is so chosen as to prevent the water boiling.

It is also possible simultaneously to use the elevation of temperature and the change in the pH value.

Particularly preferably, the gel is produced by adjusting the pH value to 3 to 8, particularly 5 to 6 and elevating the temperature to a level of 0 to 85°C at ambient pressure.

Present in the gel is an interpenetrating network of silicatic and organic network. Also, silicatic network and organic network can thereby be connected to each other, for example by covalent bonds, hydrogen bridge bonds or ionic bonds.

The organic and inorganic (silicatic) networks interpenetrate in dimensions of not more than 100 nm, preferably a maximum of 50 nm and particularly preferably a maximum of 30 nm, particularly a maximum of 15 nm. The expression "dimensions" in this case means

that in at least 50, preferably 70 and particularly 80% by weight of the networks, from each point on a network and at a distance of a maximum of 100, preferably a maximum of 50 and particularly preferably a maximum of 30 and especially a maximum of 15 nm, the limit of the corresponding organic or inorganic phase is reached. Starting on the basis of a model of interpenetrating tubes, then this number indicates the maximum tube diameter for each network. Since the networks bear at least partially on one another and may also be connected to one another, then as a rule at this distance a phase limit of organic to inorganic network phase is reached. Thus, it is also possible to speak of a mixture of organic and inorganic phase on a nanometric scale.

In contrast to the interpenetrating networks according to the invention, in the case of most known mixtures of organic and inorganic materials, the dimensions are substantially greater.

Following formation of a gel from interpenetrating organic and silica gel networks, the gel is dried. Drying can thereby take place in any desired manner so that various materials are accessible. According to one embodiment of the invention, drying is conducted under conditions which lead to a xerogel or aerogel. Sub-division into aerogels and xerogels is in this case determined according to the nature of the drying technique used, by which the solution or dispersing agent contained in the gel is eliminated. A dried gel is described as an aerogel if the solution or dispersing agent of the gel is eliminated at temperatures above the critical temperature and starting from pressures which are above the critical pressure. Consequently, no fluid-vapour phase limit is crossed and therefore there is no formation of capillary forces which lead to a gel collapse during drying. On the other hand, if the solution or dispersing agent is removed under formation of fluid-vapour interphase, then the resulting gel is a xerogel. In this case, the spatial disposition of the network alters so that the distances between the elements of a structure become substantially smaller. Methods of drying the gel to form xerogels are described for example in Annu.Rev. Mater, Sci. 1990, 20, pp. 269 et seq.; L.L.Hench and W.Vasconcelos: Gel-Silica Science.

possible by virtue of the adhesive capacity of the solutions or dispersions. Suitable methods of application are for example spraying, smoothing or spreading. Once the applied layers have dried, readily adhering heat insulating and sound absorbing surface coatings are obtained. As sound absorbing materials, the materials can be used directly or in the form of resonance absorbers since they have a low sound velocity and, compared with monolithic aerogels, a higher level of sound damping capacity.

By reason of the high inner surface, the aerogels can also be used as adsorption materials. They have typically pore sizes in the range from 5 to 100, and preferably 5 to 20. Thus, they can be used as adsorption agents for a plurality of substances which can either be adsorbed on the organic polymers used or the silica gels. Furthermore, by virtue of their through-pores, they can be used as filter materials.

Furthermore, they have barrier properties in respect of water and/or organic solvents.

Furthermore, they can be used as fillers for chromatographic separating columns, for example for chiral selection and/or separation of enantiomers. Furthermore, they are suitable as a base material for membranes.

Furthermore, they can be used in the field of electronics, for example for the production of integrated circuits (IC's).

In addition, they can be loaded with compounds which makes it possible for them to be used as sensors. For example, functional units may be included into the aerogels such as pH indicators or moisture indicators. Thus, the aerogels according to the invention can be used in a plurality of sensor applications.

In conjunction with dyestuffs, indicators and/or biomolecules as well as proteins, e.g. enzymes, transport proteins, receptors or antibodies, they are in this way usable in medical diagnostics and sensor technology.

Furthermore, they can be used for decelerating the liberation of active principles. For this, they are charged with active principles which are reversibly bonded to the networks. The bonding can take place for example via the silicate structures or possibly via an inner group present in the organic network. For example, active principles such as cholesterin and other pharmaceutical substances can be released at a slower rate. In this respect, it is possible to use the specific bonding of definite compounds to the aerogel. For instance, also the pH change makes it possible to modify the bonding relationship.

Compared with aerogels which are not modified with organic polymer networks, the aerogels according to the invention have increased flexibility and elasticity. Therefore, they can be subject to a preferably mechanical loading in which case they have considerable advantages particularly over brittle and purely inorganic aerogels.

By an appropriate choice of suitable organic polymers, the aerogels can be biocompatible so that it is furthermore possible for them to bond biomolecules such as proteins, e.g. enzymes, transport proteins, receptors or antibodies.

In the form of xerogels, the materials according to the invention may be used for appropriate applications, the pore volume being less than in the case of the aerogels. With regard to applications, reference may be made to the preceding description of the aerogels.

Drying of the gels can also be carried out under conditions which lead to a composite material. In this respect, the composite material may be calcined. To produce composite materials, the gels are so dewatered that the network structures collapse and a compact solid body is obtained which has only negligible amounts of pores or no pores at all. Typically, these solid bodies have a density of 0.8 to 1.2 g/cu.cm. The composite materials obtained can, as described in the case of the aerogels, be brought to any desired form or may be used as surface coatings. In this respect, they exhibit markedly different qualities compared with organic polymers or inorganic ceramics. In addition, the

reaction solution can, by washing with a pure solvent, be eliminated prior to subsequent drying. Possible organic solvents are generally aliphatic alcohols, ethers, esters or ketones as well as aliphatic or aromatic hydrocarbons. It is also possible to use mixtures of the said solvents. Preferred solvents are methanol, acetone, tetrahydrofurane, acetic acid ethyl ester, dioxane, n-hexane, n-heptane and toluene. Acetone is preferably used as the solvent.

The preferred object of surface modification is the introduction of covalently bonded hydrophobic surface groups which are hydrostable when used. Suitable groups are trialkyl silyl groups to the general formula $-Si(R_3)$, in which R may be the same or different and is a non-reactive organic radical such as C_{1-18}-alkyl, preferably C_1-$_6$-alkyl, preferably methyl or ethyl, cyclohexyl or also phenyl. It is also possible to use C_{2-18}-alkenyl, preferably C_{2-6}-alkenyl radicals. Particularly advantageous is the use of trimethyl silyl groups for the permanent hydrophobilisation of the material, particularly of the aerogel.

Incorporation of these groups can be carried out as described in WO 04/25149. In this case, a gas phase reaction is carried out between the aerogel and an activated derivative of trialkyl silane, for example a chlorotrialkyl silane or a hexaalkyl disilazane, see also R.Iler, The Chemistry of Silica, Wile and Sons, 1979. Also, an acetone-containing gel may be reacted with trimethyl isopropenoxy silane, see DE-C-195 02 453. The introduction of hydrophobic surface groups is not an essential prerequisite to the production of low density aerogels according to the invention but they do permit of widening of the application spectrum with respect to water-insensitive systems.

Drying is carried out after modification and generally as long as the residual solvent content is less than 0.1% by weight. Suitable drying methods are for example contact and convection drying as well as electric drying processes.

The invention is explained in greater detail hereinafter with reference to examples.

In this respect, the heat conductivity of the aerogels produced according to the invention was measured by a hot wire method, see for example O.Nielsson, G.Rüschenpöhler, G.Gross, J.Fricke, High Temperatures - High Pressures, Vol. 21, 267-274 (1989) Academic Press Inc. New York.

The modulus was measured with a three-point flexion method, see for example G.W.Scherer, S.A.Pardenek, R.M.Swiatek, J. Non-Crystalline Solids, Vol. 107, 14-22 (1988) Academic Press Inc. New York.

Example 1

From a 7% by weight sodium water glass solution, the free silicic acid is produced via an acid ion exchanger and adjusted with dilute 0.1 n soda lye to a pH value of 5.7. 100 ml of this solution are then adjusted with 10 ml of a 10% by weight dilute solution of a commercially available sulphamate modified melamine resin type Madurit® MW114 from Cassella AG, the pH value of which is likewise adjusted to 5.7 by 0.1 standard hydrochloric acid, is blended with a sol and poured into a 6 mm thick tube. Then, the sol is gelled at 85°C for 6 hours, cooled and removed from the tubes. Afterwards, the water present in the pores of the gel is exchanged for acetone until such time as the concentration of water in the acetone is less than 1% by weight. The gel obtained is dried in the heated nitrogen flow at 150°C and 1000 l/h. The solids density of the dried gel amounts to 0.28 g/cu.cm and the heat conductivity at room temperature is 47 mW/mK.

Example 2

From a 7% by weight sodium water glass solution, the free silicic acid is produced via an acid ion exchanger and is adjusted with dilute 0.1 n soda lye to a pH value of 5.7. 100 ml of this solution are then mixed with 5 ml of a solution of a commercially available sulphamate modified melamine resin type Madurit®MW114 of Cassella AG, diluted to 10% by weight and of which the pH value is adjusted with 0.1 standard hydrochloric acid to 5.7, with a sol and poured into 6 mm thick tubes. Then, the sol is gelled for 6 hours at 85°C, cooled and removed from the tubes. Afterwards, the water present in the pores

of the gel is exchanged for acetone until such time as the concentration of the water in the acetone is less than 1% by weight. The gel obtained is dried in the heated nitrogen flow at 150°C and 2000 l/h. The solids density of the dried gel amounts to 0.22 g/cu.cm and the heat conductivity at room temperature is 34 mW/mK.

Example 3

The free silicic acid is produced from a 7% by weight sodium water glass solution via an acid ion exchanger and is adjusted with dilute 0.1 n soda lye to a pH value of 5.7. 100 ml of this solution are then mixed with a solution of commercially available sulphamate modified melamine resin type Madurit®MW114 from Cassella AG which is diluted to 10% by weight and the pH value of which is likewise adjusted with 0.1 normal hydrochloric acid to 5.7, and mixed with a sol. In addition, 1% by weight (in relation to the solid fraction in the sol) of commercially available acetylene carbon black is admixed with the sol by means of "Ultrathurrax" and poured into 6 mm thick tubes. Then, the sol is gelled for 6 hours at 85°C, cooled and removed from the tubes. Afterwards, the water present in the pores of the gel is exchanged for isopropanol until the concentration of water in the isopropanol is less than 1% by weight. The gel obtained is dried in the heated nitrogen flow at 150° and 1000 l/h. The solids density of the dried gel amounts to 0.28 g/cu.cm and the heat conductivity at room temperature is 50 mW/mK.

Patent claims

1. A method of producing materials with interpenetrating organic and inorganic networks in dimensions of not more than 100 nanometres by

   (1) mixing aqueous solutions or dispersions of organic polymers capable of forming polymer networks in aqueous phase, polymer precursors or mixtures thereof and silicon dioxide components;
   (2) changing the pH value and/or thermal treatment of the aqueous solution or dispersion to form a gel consisting of interpenetrating organic and silica gel networks, and
   (3) drying the gel.

2. A method according to claim 1, characterised in that the organic polymers or their precursors are based on formaldehyde or resins, polyvinyl alcohol or poly(meth)acrylates which contain formaldehyde.

3. A method according to claim 1 or 2, characterised in that water glass, laminated silicates or silicic acids are used as silicon dioxide components.

4. A method according to one of claims 1 to 3, characterised in that fillers in the form of particles, fibres, weaves, fleeces, mats or their mixtures, functional substances such as dyestuffs, indicators, biomolecules, receptors or their mixtures are added to the aqueous solution.

5. A method according to one of claims 1 to 4, characterised in that in the materials and prior to drying, the water is replaced by an organic solvent and the silica gels are organically modified by silylation.

6. A method according to one of claims 1 to 5, characterised in that drying is carried out under conditions which lead to a composite material, the composite material being capable of being calcined.

7. A method according to one of claims 1 to 5, characterised in that drying is carried out under conditions which lead to a xerogel or aerogel.

8. Materials with interpenetrating organic and inorganic networks of dimensions not exceeding 100 nm and which can be produced by a method according to one of claims 1 to 7.

9. Aerogel consisting of interpenetrating organic and inorganic networks with a density of not more than 0.6 g/cu.cm and in dimensions of not more than 100 nm.

10. Use of aerogels according to claim 9 or aerogels which can be produced according to the method in claim 7 for the production of mouldings or surface coatings having heat insulating, sound insulating and/or adsorption properties and/or barrier properties in respect of water and/or organic solvents.

11. Use of composite materials which can be produced according to the method according to claim 6 for the production of granulates or ceramic mouldings.

12. Moulding or surface coating consisting of materials according to claim 8 or 9.

13. A method of producing mouldings or surface coatings according to clam 12, characterised in that the aqueous solutions or dispersions are introduced into a form or are applied to a surface, after which a gel is formed and dried.

14. Use of materials as defined in one of claims 6 to 12 in conjunction with dyestuffs, indicators, receptors, enzymes and/or biomolecules for medicinal, diagnostic and sensor technology.